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MICROMETEOROLOGICAL PHENOMENA OF
UNDERWATER NUCLEAR EXPLOSIONS

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MICROMETEOROLOGICAL PHENOMENA OF UNDERWATER NUCLEAR EXPLOSIONS

by

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ABSTRACT: The above-surface phenomena of Test Baker in Operation Crossroads (1946) are described in detail with emphasis on the primary base surge. Some recent theoretical results concerning the surge structure and behavior are summarized. The base surge from the Teapot ESS Underground Test is briefly described and compared with the Baker surge.

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The mater.al in this report was presented as a talk at the National Conference on Micrometeorology at Salt Lake City, Utah on 14 October 1964. This subject has been investigated at the Naval Ordnance Laboratory since 1950; however, the recent developments summarized here were results obtained during 1963 and 1964 under Task FR-70, titled "The Physics of the Base Surge."

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MICROMETEOROLOGICAL PHENOMENA OF UNDERWATER NUCLEAR EXPLOSIONS

It is well known that a nuclear explosion on the surface of the ground or water will produce spectacular cloud phenomena, mainly of the convective type. However, a shallow underwater burst also results in the generation of a variety of interesting cloud effects, which are of considerable importance for the spread of radioactive contaminants. The best known nuclear explosion of this type is the Baker test in Operation Crossroads, conducted in 1946 at Bikini. As this shot set possibly 6 million tons of sea-water into violent motion and raised about 600,000 tons of vapor and liquid to heights ranging up to 10,000 feet in a humid tropical atmosphere, it was a virtual factory for the production of clouds.

Slide 1 shows the early formation of a ring of water jets surmounting a dome of spray at Test Baker. The beginning of a cloud formation in the suction phase of an air shock wave is visible as a collar about half way between the lagoon surface and the top of the jets. This is the same phenomenon which occurs in a Wilson cloud chamber.

SLIDE 1 CROSSROADS BAKER 0.8 SEC

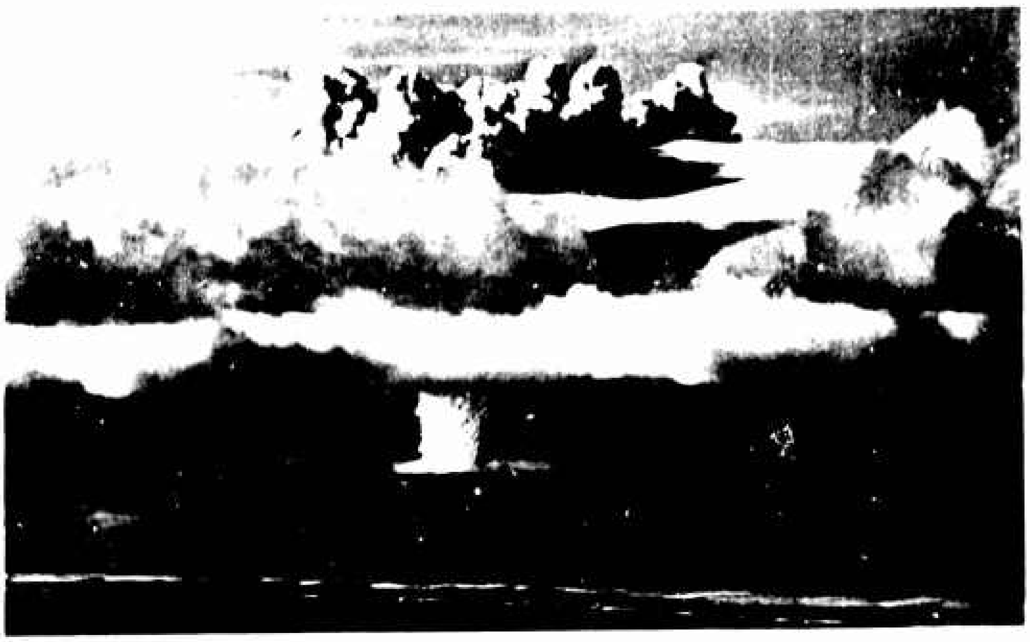
SOURCE: FILM NO. AF-614
FRAME 10

On Slide 2 the condensation cloud has grown to a hemisphere over a mile in diameter. Although it is of some interest, this is a cloud effect we would prefer not to see, because it obscures the development of more important phenomena. The only evidence of the structure of the surface phenomena is the top of the ring of water jets.

SLIDE 2 CROSSROADS BAKER 3.1 SEC

SOURCE: FILM NO. AF-644
FRAME 1

On Slide 3 we see the vestiges of the condensation cloud, which expanded laterally at the altitude of the existing clouds and then slowly dissipated. The cauliflower cloud and column are becoming visible. The column is about 2000 feet wide at this time.



SLIDE 3 CROSSROADS BAKER 6.4 SEC

SOURCE: FILM NO. AF-614
FRAME 17

The aerial view on Slide 4 was taken a few seconds later. The condensation clouds have thinned and the column is spilling over in the form of jets. A new white cloud is rising within the cauliflower.

SLIDE 4 CROSSROADS BAKER 9.0 SEC

SOURCE: FILM NO. AF-609
FRAME 8

Although it was not visible at early times, a large solitary wave formed around the edge of the cavity which was blown in the water by the explosion. This huge wave spilled over and broke into a series of jets which emerged from the base of the column about 11 seconds after the explosion. Slide 5 shows the ring of spray formed by the breakup of these jets. The ring is called a base surge.

The spray and the air it entrained flowed outward as a density current, possibly 5 times as dense as the surrounding atmosphere. The liquid water content was about 5000 gm/m^3, and a maximum drop diameter of 270 microns was calculated.

For about half a minute the surge behaved like a micro-cold front, under-running the surrounding air and lifting it with little mixing across the interface. At the beginning of this stage, shown on Slide 5, machine calculations indicate that the drops coalesced rapidly because of the high concentration and formed a bimodal distribution which was essentially a cloud spectrum and a raindrop spectrum. The raindrops fell out while the cloud droplets continued to flow radially along the surface.

SLIDE 5 CROSSROADS BAKER [illegible] SEC

SOURCE FILM NO. AF-637
FRAME 6

Slide 6 is presented to show the second base surge. The mechanism of formation was considerably different, as this surge developed from the subsiding dense aerosol in the column. The liquid water content of this ring of cloud was initially about 200 gm/m^3. It was soon destroyed by the massive fallout from the cauliflower.

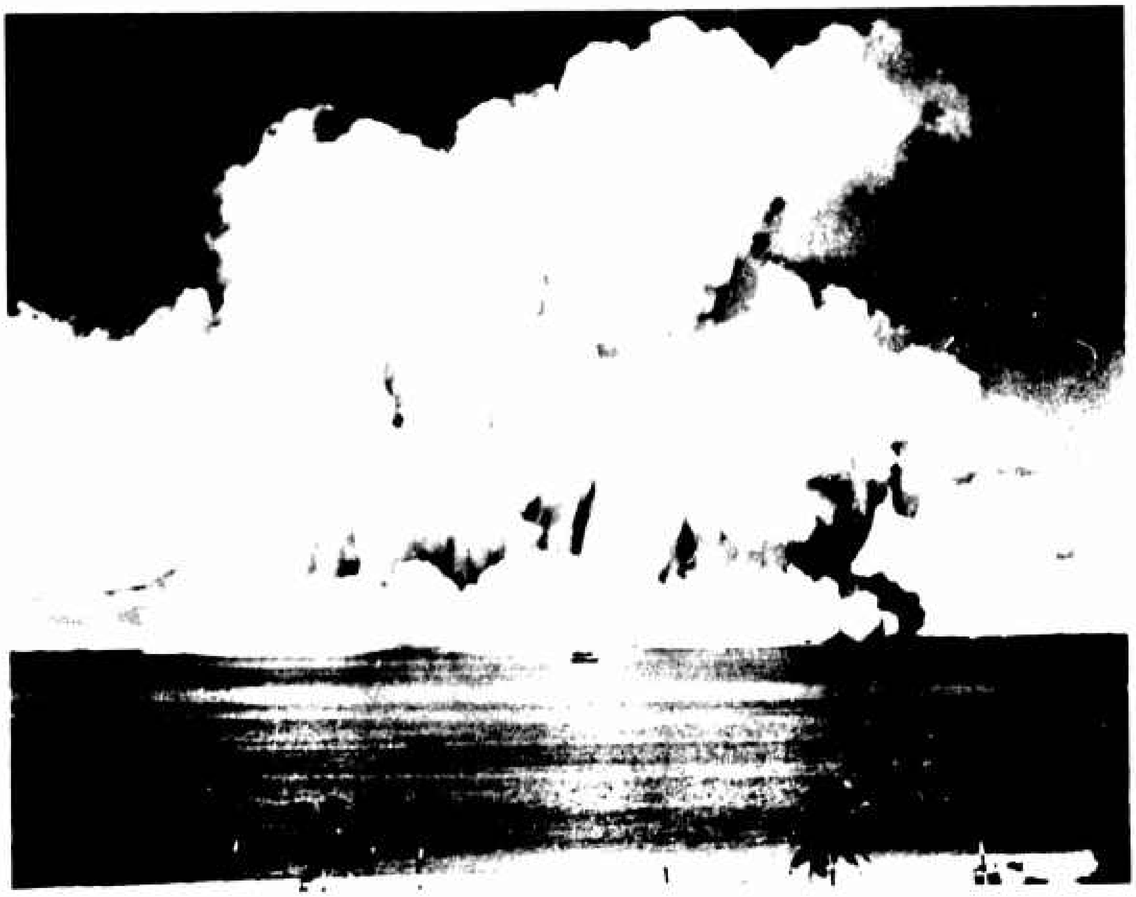
SLIDE [illegible] CRO[illegible] ROAD [illegible] 30 SEC

SOURCE: FILM NO. AF-[illegible]
FRAME 14

In the meantime the rainout of large drops rapidly reduced the bulk density in the primary surge to ambient level. This decrease in liquid water content occurred initially at the top of the surge and at this stage the upper portion of the surge became similar to the edge of a jet of air moving laterally through the atmosphere. Turbulent mixing began across the upper surface, as shown in Slide 7.

FILM NO. [illegible]
FRAME 2

Slide 8 shows the further development of this process. As a result of the free turbulence in the mixing zone at the top of the surge, portions of the surge were transported upward rapidly. The coefficient of eddy viscosity in the mixing zone was estimated to be about 10^6 cm^2/sec.



SLIDE 8 CROSSROADS BAKER 59 SEC

SOURCE: FILM NO. AF-644
FRAME 20

In Slide 9, the massive fallout has about disappeared and the surge and upper white cloud resemble natural clouds in structure and appearance. The top of the surge is at the lifting condensation level of the atmosphere, at a height of 1500 feet.

[illegible] CROSSROADS BAKER [illegible] SEC

SOURCE: FILM NO. AF-[illegible]
FRAME [illegible]

In Slide 10, rainfall has developed within the surge and the top is overlain by stratiform clouds which formed in the lifted air. The surge aerosol has taken on a dense cumuliform appearance as a result of new condensation within. The surge cloud ring has a base about 1000 feet above the surface of the lagoon. Rain has also formed in the central white cloud, which has almost completely dissolved.

SLIDE 10 CROSSROADS BAKER 162 SEC

SOURCE: FILM NO. AF-6[illegible]
FRAME 5[illegible]

Slide 11 shows the penetration of the upper clouds by the cumulus cloud turrets in the surge. The jet-like action has ended and a natural process of convection is well under way because of the convective instability of the atmosphere. Rainfall is continuing, but the visual range is increasing, as shown by the re-appearance of target vessels.

259 SEC

In Slide 12, the Baker surge resembles a ring of natural cumulus clouds. The base coincides with the base of the trade wind cumulus in the area. Two examples of pileus clouds are visible.

FIG. 12 [illegible] [illegible]

[illegible]

The appearance of the Baker base surge at a relatively late time is shown in Slide 13. The entire formation moved at the speed of the wind at cloud altitudes and soon left the lagoon, leaving a deposit of radioactive material over its path.

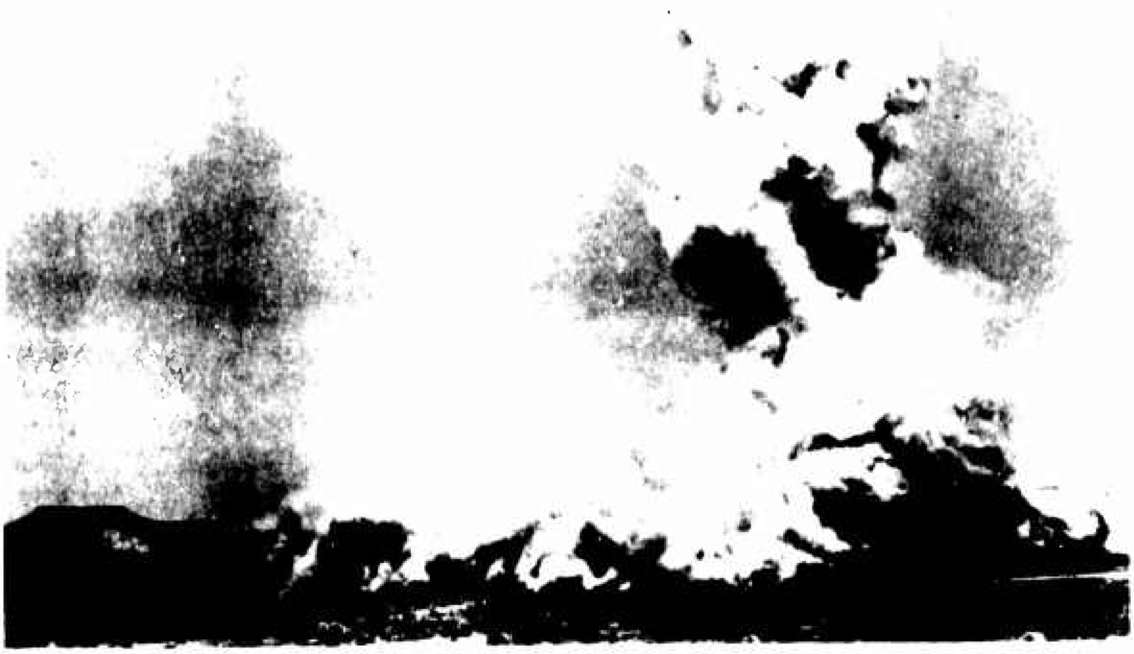
In a drier, more stable, atmosphere the convective stage would not develop and the surge cloud would gradually become diluted and would evaporate. However, radioactive particles would remain airborne.

SLIDE 16 CROSSROADS BAKER 432 SEC

SOURCE: FILM NO. AF-609
FRAME 152

Teapot ESS was a shallow underground nuclear test conducted at the Nevada Test Site in 1955. As shown in Slide 14, a large base surge formed, which resembled a water surge in general appearance. However, the raincut of soil particles was relatively slow and the surge retained a rather high bulk density. No cloud effects occurred because of the dry atmosphere.

Slide 15 shows the gradual mixing of the dust surge with the air. The dust cloud eventually dissipated as a result of atmospheric diffusion but remained visible for a longer time than a comparable water cloud would, permitting the recording of its motion by means of photography. Consequently, a study of base surges from underground tests in dry climates may lead to a better understanding of the behavior of water surges in a dry atmosphere where convective cloud development does not occur.



SLIDE 15 TEAPOT ESS 2/3 [illegible]

SOURCE: FILM NO. 28569
FRAME 46